Via Cleanliness after Development of Photo-BCB Advanced Electronic Resin using Scanning Photoelectron Microscopy

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Introduction

Photo-BCB (CYCLOTENE™ 4024 or 4026 Advanced Electronics Resins) are photosensitive polymers developed by The Dow Chemical Company Advanced Electronic Materials Laboratory for use in micro-electronics applications [1]. This material can be used as thin films for wafer level applications where a protective layer is needed for passivation, chemical resistance, or electrical insulation. It is a negative tone photosensitive polymer. One important issue to understand is how completely the polymer is removed from the surface in unexposed areas during developing. The material left in unexposed areas after developing has been called "scum" and procedures to "descum" these areas by plasma cleaning have been developed, but it is difficult to determine the quality of the descumming in a precise sense. One method used to sense the presence of the scum in vias is scanning thermal microscopy [2]. XPS provides a more chemically sensitive picture of the residue but laboratory based XPS measurements are limited presently to a practical resolution of about 30 μm.

SPEM provides almost two orders of magnitude better spatial resolution, than does in-lab based XPS and thus is very helpful in the analysis of descumming issues. Despite the existence of uncompensated surface electrical charging, of up to hundreds of volts, it was possible to interpret microprobe XPS spectra and images obtained for these important materials.

Results

Synchrotron based scanning photoelectron microscopy (SPEM) at the Advanced Light Source [3] was used to characterize two different electronic devices made with photo-BCB (Cyclotene* 4024 or 4026). One device had been developed and descummed and was part of a batch of devices which were known to be "good". The other device had been developed and cured, but not descummed.

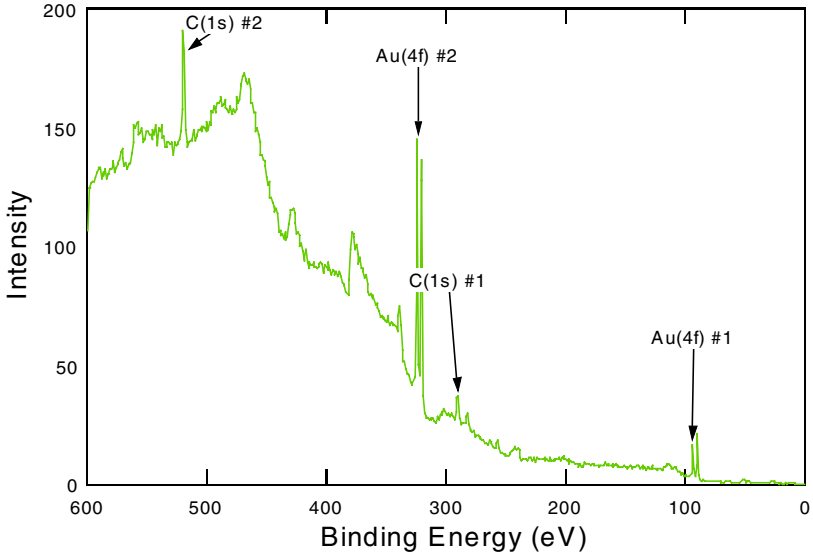

Figure 1. Survey XPS spectrum of the E456 sample measured on the SPEM without any zone plate so that the data comes from an area about 1.5 x 0.5 mm in size (elliptical). The spectrum indicates at least two separate regions with different surface electrical charge.

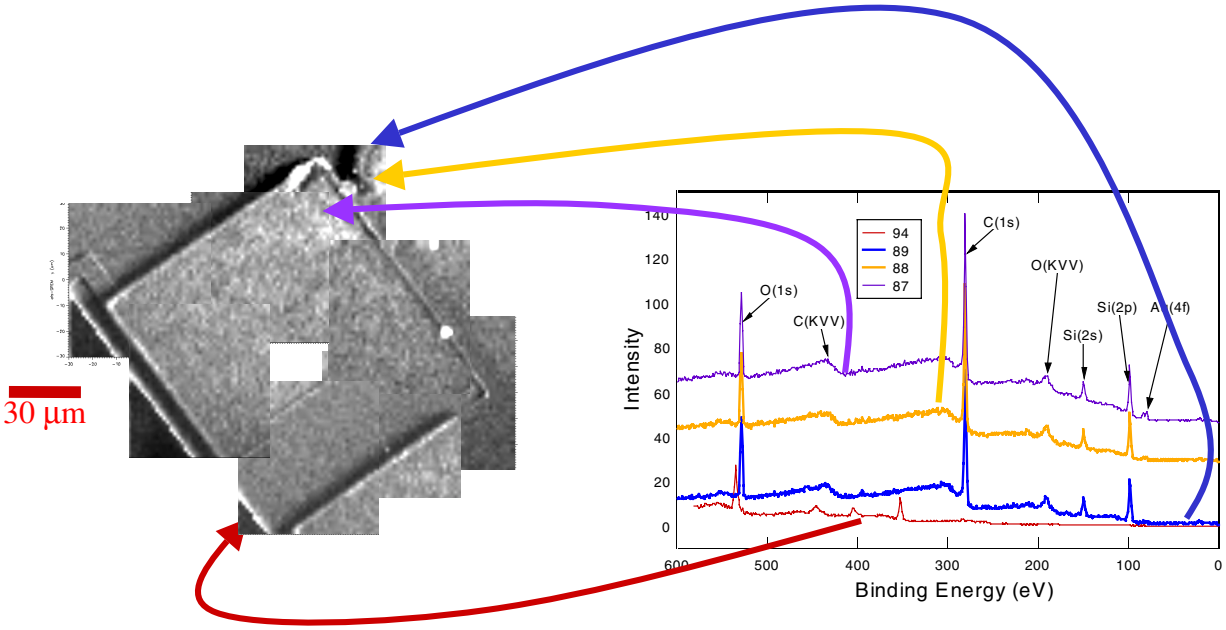

Figure 2. A montage of SPEM images that together provide an image of most of a large gold solder pad located near the edge of the die that had been developed but not descummed. The differently colored arrows indicate where the microprobe XPS spectra in the graph at right were obtained. The energy scale is uncalibrated.

Since the devices consisted of large areas of the surface which were electrically insulating (polymer dielectric), with smaller metallic (gold) surfaces, the first concern in these experiments was to determine the extent of surface electrical charging and what influence the charging had on our ability to acquire useful XPS data. We discovered that when we measured large area XPS spectra (zone plate out of beam) the spectra consisted of signals from regions of the surface that were charged and areas that appeared not to be charged significantly. An example of such a spectrum is included as Figure 1. Two sets of XPS peaks are identified in this spectrum and are labeled by their spectroscopic terms. One set was from areas that were charged by about 200 V relative to the other. The XPS peaks were identified by their individual shapes (for instance the Au 4f peak is a doublet with a splitting of 3.65 eV) and relative separations from other peaks (201 eV between the main C(1s) and Au 4f peaks , for instance).

Despite the surface electrical charging, it was possible to easily acquire sensible images using the zone plate and small area spectra were not complicated by multiple charging states. Figure 2 and 3 present examples of images and spectra from gold soldering pads on test electronic structures. One device (Figure 2) had been patterned and developed by solvent rinsing to remove the polymer in the unexposed areas, and the other device (Figure 3) had been patterned and developed followed by a subsequent plasma descumming process. The images were obtained from the XPS signal at the Au 4f energy without subtracting any background signal. Thus the image contains information about the surface cleanliness, but convolved with other (undefined) effects. From the microprobe spectra, however, one can calculate the relative surface coverage of contaminants and thus determine the quality of descumming procedures.

In Figure 2, the rectangular feature that looks like a mound delineates the edges of the gold pad. Spectra taken outside this border have no Au 4f peak in contrast to spectra from within (purple spectrum). At top there appears to be a gold interconnect feature which also is visible (yellow spectrum). In Figure 3, two different types of areas are visible, one much darker than the other. The lighter area is the gold solder pad and the darker area is the polymer.

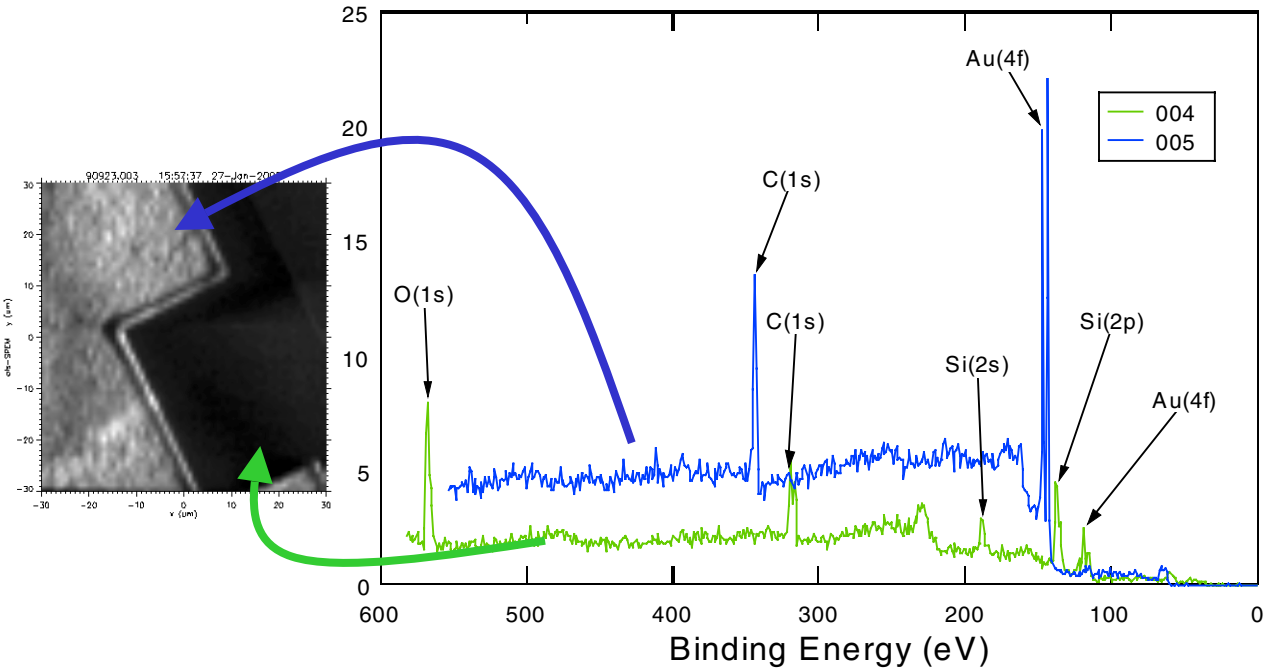

Figure 3. SPEM image of an area with a gold soldering pad, on the device that had been developed and descummed (left). The image was measured using an analyzer window covering the Au(4f) spectral region. At right spectra obtained from the points indicated in the image by the arrows are graphed. The energy scale is uncalibrated.

Summary

Although we have not attempted to quantitate these data, from the relative intensities of the Au 4f peaks one can compare the relative cleanliness on a qualitative basis for the spectra observed in Figures 2 and 3. The Au 4f spectrum for the gold pad in Figure 3 is much more intense than any spectra observed from the sample in Figure 2. These samples had been exposed to air for several months prior to analysis and metals such as gold always are found to pick up some carbon based contaminants when exposed to air, so that the intensity of the Au 4f peak in Figure 3 suggests the surface is very clean. The spot size for these analyses was about 1-200 nm which is about 2 orders of magnitude better than that offered by lab-based instruments. By measuring small spot spectra in several locations around the gold pads one can derive an excellent understanding of the quality of descumming procedures.

References

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